UNIVERSITI PUTRA MALAYSIA

USE OF SCRAP TYRES IN EARTH RETAINING STRUCTURES

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By

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Abstract of the thesis submitted to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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April 2008

Supervisor : Professor Bujang Bin Kim Huat, PhD

Faculty : Faculty of Engineering

In Malaysia, a huge quantity of scrap tyres are produced every year resulting in environmental hazards. In addition, present recycling techniques for scrap tyres consume only a very small amount of the unwanted tyres. With this in mind, this research aims to assess the technical feasibility of using whole scrap tyres as one of the elements of retaining structures. The purpose of this thesis is to demonstrate, through an experimental laboratory investigation and full scale testing, that a reinforced tyre system from scrap passenger car tyres can be used to produce engineered retaining structures for civil engineering construction. This research study is divided into three main parts: a study on the physical and mechanical properties of passenger car tyres and attachments, behaviors of reinforced scrap tyre retaining structures with cohesive material, and cost comparison of a reinforced scrap tyre system with other conventional retaining structure systems.

It was found that the physical and mechanical properties of scrap passenger car tyres are tremendously strong. Various attachment systems were studied in terms of mechanical properties and costs. Polypropylene rope was found to be the most cost effective attachment system with comparable strength to scrap tyres.

A 5m high full scale reinforced scrap tyre system been constructed using in-situ cohesive material. 2100 scrap passenger car tyres were used for the construction of a 7m long x 5m high slope. Instrumentation like pressure cells and settlement plates were installed to monitor the behavior of the system. Methods of construction and precautions during the construction stage were discussed in detail in this study. It can be concluded that the reinforced rubber tyre system is suitable for application in retaining structures. It improves the mechanical properties of the soil either anisotropically or isotropically.

Cost comparison between reinforced scrap tyre systems and other retaining structure systems were studied. Reinforced scrap tyre systems can be used as alternative cost effective retaining structure system with wall heights less than 6m. This system would be one of the best recycling techniques for scrap tyres because it consumes huge amounts of unwanted tyres with minimum energy consumption.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

KAJIAN PENGGUNAAN TAYAR SISA UNTUK DINDING PENAHAN

Oleh

LOH WOOI CHUAN

April 2008

Pengerusi : Professor Bujang Bin Kim Huat, PhD

Fakulti : Kejuruteraan

Di Malaysia, banyak tayar sisa dihasilkan setiap tahun dan menyebabkan pencemaran alam sekitar. Kaedah kitar semula tayar sisa yang sedia ada hanya dapat mengitar semula kuantiti tayar sisa yang terhad and kebanyakan tayar sisa dibuangkan ke tapak lupusan. Untuk mengatasi masalah tayar sisa, kajian ini mengkaji keberkesanan mengitar semula tayar sisa sebagai bahan binaan dalam pembinaan dinding penahan. Kajian ini akan menunjukkan proses tayar sisa yang sepatutnya dibuang ke tapak pelupusan dikitar semula dan dijadikan bahan binaan dalam dinding penahan. Kaedah ujikaji, ujian dan percubaan pembinaan skala sebenar dinding penahan daripada tayar sisa dilakukan untuk mennunjukkan keberkesaan dinding penahan yang innovatif untuk penggunaan dalam bidang kejuteraan awam. Kajian ini dibahagikan kepada tiga bahagian. Bahagian satu merangkumi kajiaan terhadap sifat fizikal and sifat mekanik tayar sisa kereta and sistem ikatan tayar. Bahagian dua merangkumi kajian terhadap sifat dan keberkesaan apabila dinding penahan tayar sisa diisi dengan tanah liat. Bahagian ketiga akan mengkaji

perbandingan dari segi kos pembinaan dinding penahan tayar sisa dengan sistem dinding penahan yang sedia ada di Malaysia.

Didapati sifat fizikal and mekanik tayar sisa adalah sangat kuat. Banyak sistem ikatan tayar sisa dikaji untuk mengikatkan tayar sisa menjadi lapisan tayar. Kos dan kekuatan pelbagai sistem ikatan telah dikaji. Tali Polypropylene didapati paling ekonomi dan kuat berbanding dengan sistem ikatan yang lain.

Satu percubaan pembinaan skala sebenar dinding penahan tayar sisa setinggi 5m telah dibina menggunakan tanah liat yang terdapat di tapak pembinaan. 2100 tayar sisa telah dikitar semula untuk membinaan dinding penahan setinggi 5m and selebar 7m. Peralatan seperti pengukur tekanan tanah dan plat pemendapan telah dipasang dalam dinding penahan percubaan untuk mengkaji sifat dan keberkesanan sistem inovatif ini. Kaedah pembinaan dan langkah berjaga-jaga semasa pembinaan telah dibincang dalam laporan ini. Kesimpulannya, dinding penahan tayar sisa sesuai dan selamat digunakan untuk tujuan kejuruteraan awam.

Perbandingan kos pembinaan dinding penahan tayar sisa dengan sistem dinding penahan yang sedia ada telah dikaji. Dinding penahan adalah ekonomi untuk ketinggi kurang daripada 6m. Penggunaan tayar sisa untuk pembinaan dinding penahan adalah cara yang sesuai untuk mengitar semula tayar sisa kerana kuantiti tayar sisa yang banyak dapat digunakan.

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I certify that an Examination Committee has met on 14th April 2008 to conduct the final examination of Loh Wooi Chuan on his Master of Science thesis entitled "**Use of Scrap Tyres in Earth Retaining Structures**" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the degree of Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Professor and Dean
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Date: 14 August 2008

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently submitted for any other degree at Universiti Putra Malaysia or at any other institutions.

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LOH WOOI CHUAN
Date: 23 June 2008

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CHAPTER 1

INTRODUCTION

1.1 Background

Soils, unlike solid rocks, generally have low strength. It is therefore often not possible to cut or build a high vertical cut and slope in soils without the aid of an earth retaining structure (Huat et al., 2006). The purpose of an earth retaining structure is to withstand the forces exerted by the retained ground, and transmit these forces safely to the foundation (GCO, 1998). Retaining structures are one of those structures that are often built to retain ground for construction of infrastructure, building platform and also to repair slope failure. Their typical use can be shown in Figure 1.1. A retaining structure and each part of it, is required to fulfill fundamental requirements of stability, stiffness, durability, etc., during construction and throughout its design life (GCO, 1998). Many types of retaining structures are in use in Malaysia. Those common types of retaining structures including stone pitching wall, crib walls, gabion walls, reinforced concrete wall and mechanical stabilized earth (MSE) wall.

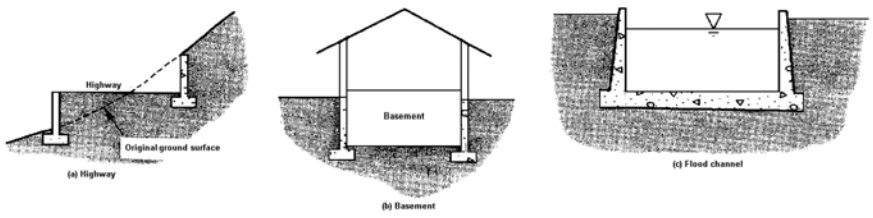

Figure 1: Typical Application Of Retaining Structures. (Huat et al, 2006)

Rapid development since decades ago has brought Malaysia growth in population, growth of economy and improvement of lifestyle. Limited suitable low lying areas have increased the demands of development towards hilly areas. A good land transportation network system is needed in order to accomplish the rapid development. Hence, more highways and road upgrades are needed for passing through hilly terrain. Referring to a survey done by the Public Works Department of Malaysia in 2003, the total length of roads has increased from 21,914km in 1980 to 78,433km in 2003 and an estimated 30% of the roads traverse hilly and mountainous areas (PWD Malaysia, 2004a). In year 2000, total cost for state road maintenance was RM 335 million and 20% of it or RM 67 million was allocated to slope maintenance (JICA & JKR, 2001). The rapid development of hilly areas for road works and housing has also caused an increase in slope instability problems. This fact can be proved in statistics of landslides and fatalities reported between 1974 to 2004 in Malaysia as shown in Figure 1.2. It is clearly shown that the need of earth retaining structure is increasing, either for slope remedial works or our infrastructure system.

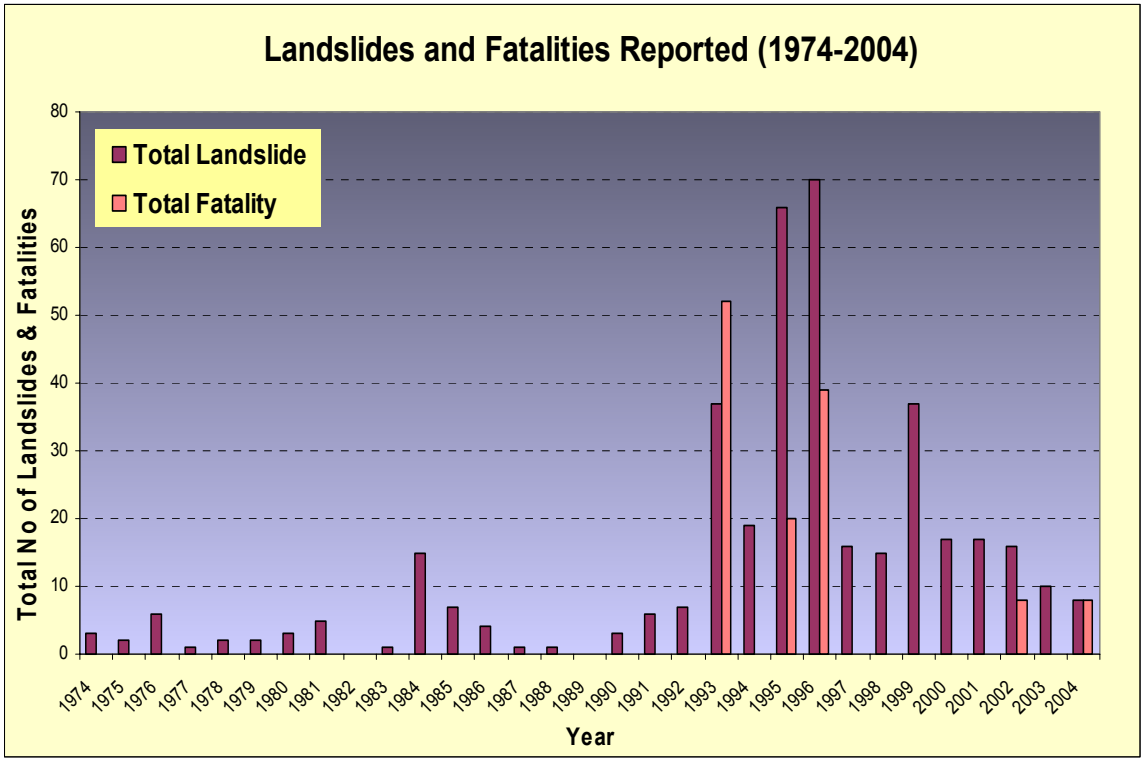

Figure 1.2: Statistic Of Landslides And Fatalities Reported Between 1974 To 2004 In Malaysia. (PWD Malaysia, 2004a)

Used tyres are a blight of our civilization. In year 2002 alone, 8,198,745 units of scrap tyre been generated in Malaysia and 60% of the scrap tyres are disposed via unknown route (Sandra, 2006). The figure provided is not including millions of scrap tyres which previously already stockpiled or disposed in our country. Today, scrap tyre issue has become a serious national problem in many developing countries as well as developed countries (RMA, 2007;UTWG, 1998;Chang, 2001). Research into the application of scrap tyre for civil engineering fields has started some years back in developed countries. Scrap tyres could be used as subgrade fill and embankment fill, backfill for wall and bridge embankments, septic system, drain fields, beach erosion control, and sound attenuation system (RMA, 2007). Example of application of whole tyres as construction

materials can be found in Long (1993) and Garga & O'Shaughnessy (2000), while those of shredded tyres are given by Drescher & Newcomb (1994), Abbott (2001), Amirkhanian (2001), Okba et al. (2001), and RMA (2007). In Malaysia, the present local recycling techniques of scrap tyres only consume a very small amount of the unwanted tyres. The percentage of scrap tyres being recycled is not comparable to the growth in scrap tyres (Sandra, 2006). Thus, a need still exists for the development of additional uses for scrap tyres in Malaysia. With the above problems in mind, feasibility study on potential use of whole scrap tyres for earth retaining structures has been investigated. The use of whole tyre without shredding is probably more preferable because energy is not wasted in further processing.

Soil is the most abundant and least expensive construction material. Soil is strong particularly loaded in compression, but soil is weak in tension. With the inclusion of reinforcement that are strong in tension like steel bar, geogrid, geotextile, it can produce a composite material that combine the best load carrying features of both component (NCHRP, 1987). This resultant composite material is referred as reinforced soil. Reinforced soil concept been widely used to construct earth retaining structure. When numbers of whole scrap tyres are tied together to make a mat configuration, filled with soil, and then placed in successive layers, the resulting structure can be used as a retaining structure. The above mentioned concept of using whole scrap tyre to reinforce soil was done in France in 1976 (Long, 1996). Until 1996, more than 500 earth retaining structures using scrap tyres and soil have been built in France, Algeria, England, Canada and USA (Long, 1996). Whole scrap tyres have been successfully used to construct earth